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REVIEW

MYCORRHIZAL RELATIONSHIPS IN LYCOPHYTES AND FERNS

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ABSTRACT

Mycorrhizae, i.e., symbiotic associations between fungi and plant roots, occur in about 80% of land plant species and have been shown to benefit both the fungus (carbon uptake) and plant (nutrient and water uptake, protection against pathogenic fungi). We here provide a brief overview of the state of knowledge of mycorrhization in ferns. Only about 62% of species studied to date have mycorrhizae, with arbuscular mycorrhizal fungi (mainly Glomeromycta) being the dominant partners, while other associations are made with ascomycetes and the so-called Dark Septate Endophytes. There is no clear phylogenetic signal in mycorrhization among ferns, with both basal (e.g., Anemiaceae, Gleicheniaceae, Cyatheaceae) and derived families (e.g., non-grammitid Polypodiaceae, Tectariaceae, Aspleniaceae) having <50% of species mycorrhizal. Ecologically, epiphytes have lower degrees of mycorrhization than terrestrial species, with aquatic taxa almost completely lacking mycorrhizae. This probably reflects the requirements of the fungi. There are no experimental studies on the benefits of mycorrhizae for ferns, but field experiments suggest that there is a fine balance between positive and negative effects, so that many fern species have disposed of the fungi either generally or facultatively. Much remains to be learnt about mycorrhization in ferns, especially in an evolutionary context in comparison with bryophytes and seed plants.

INTRODUCTION

The term mycorrhiza (*pl.* mycorrhizae) was introduced by Frank (1885) for structures in angiosperm roots caused by fungi and translates as "fungus root". Since then it has been shown that it is one of the most common and important symbioses in the land plants (Brundrett, 2002; 2004; 2009), even in plants like bryophytes and Psilotaceae that lack roots. It is estimated that ca. 80% of all land plants engage either in facultative or obligate mycorrhizal associations (Trappe, 1987; Wang & Qiu, 2006; Brundrett, 2009).

It is likely that the colonization of land by early land plants was facilitated by mycorrhizae (Pyrozinski & Malloch, 1975; Remy et al., 1994; Blackwell, 2000; Selosse et al. 2015), even before roots first arose (Taylor et al., 1995; Brundrett, 2002; Kenrick & Strullu-Derrien, 2014). This assumption is based on the presence of structures very similar to extant symbiotic Glomeromycota in the earliest tracheophyte fossils from the Rhynie Chert (Remy et al., 1994; Strullu-Derrien & Strullu, 2007; Selosse et al., 2015)

and supported by the conserved nature of the genes regulating mycorrhizal associations across all land plant lineages (Wang et al., 2010).

Mycorrhizal fungi are known to provide numerous benefits to their plant hosts (Selosse & Rousset, 2011). They enhance nutrient uptake, especially of phosphorous (Siddiqui & Pichtel, 2008), increase drought tolerance by facilitating water uptake (Faber et al., 1991; Warren et al., 2008), and compete with parasitic fungi thus protecting plants from parasitic fungal infections (Newsham et al., 1995; Brundrett, 2002). In return, the fungal partners receive carbohydrates from the host plant (Selosse & Rousset, 2011). The intensity of this symbiosis may vary with external ecological factors (Allen et al., 2003; Antunes et al., 2011) and apparently can be regulated more actively by the plant host than by the fungal symbiont (Barker et al., 1998; Jones et al., 2004).

Most research on mycorrhizae has been conducted on seed plants because of their dominance, diversity and economic importance (Brundrett, 2004; 2009). In recent years, the scientific focus has shifted more to the origin of this symbiosis and hence to its presence in old land plant lineages like extant bryophytes and lycophytes (Read et al., 2000; Rimington et al., 2015). Mycorrhizae in ferns have been regularly screened for but rarely been in the focus of physiological or synthetic studies combining ecology and phylogeny (Wang & Qiu, 2006; Brundrett, 2009).

In the present paper, we provide a brief overview of the still incomplete knowledge of mycorrhization in lycophytes and ferns (for simplicity called ferns in the following).

TYPES OF MYCORRHIZAE

Four major types of mycorrhiza have been distinguished (Barker et al., 1998; Smith & Read, 2008; Siddiqui & Pichtel, 2008) with some characteristic deviations and aberrations in some major clades of host plants (Figure 1; Brundrett, 2002; 2004).

Arbuscular mycorrhiza (AM) is an endosymbiosis, in which the fungi penetrate the cell walls of the root cortex and form characteristic organs in the living cells for nutrient exchange, the so-called arbuscules and vesicles (Figure 2a,b; Bonfante & Genre, 2008). It is the most common, and probably the ancestral form of mycorrhizae (Field et al., 2015a), occurring in ca. 80% of extant land plants (Wang & Qiu, 2006; Brundrett, 2009). The fungal partners are aseptate Eumycota, in the majority Glomeromycota (Schüßler et al., 2001), which are asexual and obligate symbionts (Brundrett, 2004; 2009). In some basal lineages of landplants (hornworts, some liverworts and lycophytes, a few ferns), Mucoromycotina, which are either basal to or sister to Glomeromycota, may also form a similar endomycorrhiza but without the presence of arbuscules (Desirò et al., 2013; Strullu-Derrién et al., 2014; Field et al., 2015a, b).

Ectomycorrhizae (ECM) are mainly formed by the more derived septate Ascomycota and Basidiomycota (Taylor & Alexander, 2005; Taylor et al., 2010) but in a few cases also endogonalean fungi (Mucoromycotina, Hibbet et al., 2007). They build an internal network of hyphae that surround the intact root cells (Hartig net) and an external hyphal sheath around the root tips (Smith & Read, 2008; Brundrett, 2004). ECM occur in 2.0–4.7% of seed plants but dominate among tree species in temperate and boreal zones families (Smith & Read, 2008; Brundrett, 2009). Until now, ECM have not been confirmed for ferns. It has been suggested that ferns shift from AM to ECM in forests where ectomycorrhizal tree species are dominant (Cooper, 1976; Iqbal et al., 1981), but the claim that the investigated roots really belonged to ferns has been strongly contested (Smith & Read, 2008; Brundrett, 2002). Fungal symbioses interpreted as derivations of ECM are the Arbutoid mycorrhiza and the Monotropid mycorrhiza (Brundrett, 2004).

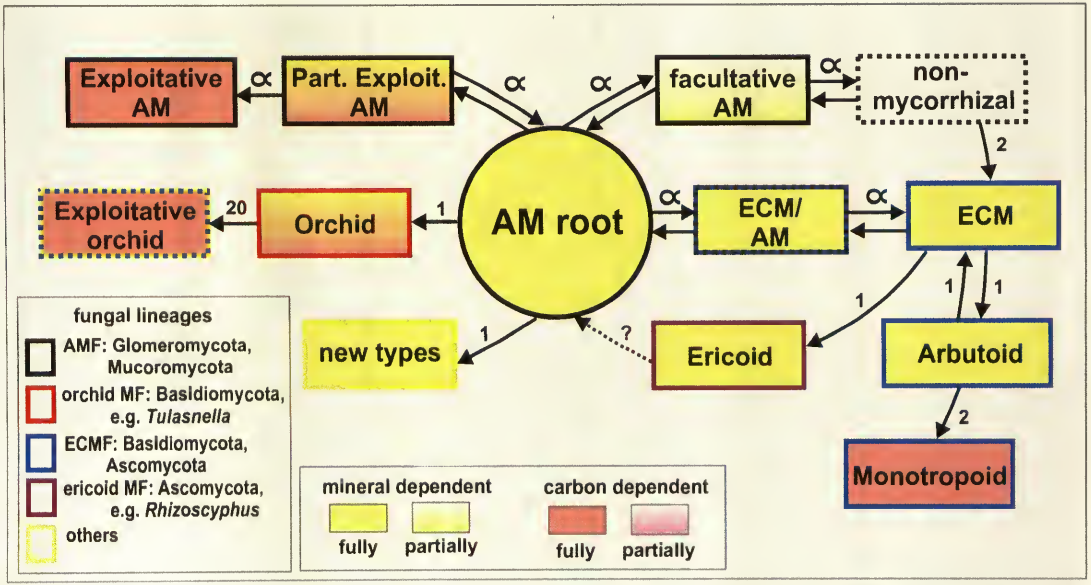

Figure 1. Diagram of the assumed relationships between the different main types of mycorrhizae (AM, ECM, ericoid, orchid) and their modifications (facultative, exploitative, mixed) based on studies of all land plants. For ferns, only AM are confirmed; exploitative AM occur in some gametophytes; ECMF and ericoid MF have been found in some lycophytes and ferns but without expressing the regular phenotype of the mycorrhiza (MF = mycorrhizal fungi). Numbers above arrows indicate instances of transitions (α = many). Adapted from Brundrett (2002)

but these are also not reported for ferns.

Ericoid mycorrhizae are formed with septate Ascomycota, which all are primarily decomposers and saprophytes (Hibbet et al., 2007). They are uncommon but typical of Ericaceae (Cullings, 1996; Brundrett, 2004) and some other plant groups occurring on nutrient-deficient substrates characterized by low primary production (Cairney & Meharg, 2003). Typical of this symbiosis is that the hyphae enter through root hairs and form hyphal coils in cortical cells (Read, 1996). ascomyceta infections of the Ericoid type have been reported for tropical ferns, mainly epiphytes, such as *Elaphoglossum*, grammitid ferns, *Hymenophyllum* and *Trichomanes* (Schmid et al., 1995; Lehnert et al., 2009). Records of the so-called Dark Septate Endophytes (DSE) in ferns (Dhillion, 1993; Jumpponen & Trappe, 1998; Fernández et al., 2008) may include still unrecognized Ericoid mycorrhizae since the taxonomic identity of most of these fungi is unknown (Jumpponen, 2001; Rains et al., 2003). Like the Ericoid mycorrhizal Ascomycota, DSE are more common in epiphytic fern species (Kessler et al., 2010).

Orchid mycorrhizae involve a small group of Basidiomycota (Brundrett, 2002), and are characterized by the initial carbon dependency of the host plant seedling on the saprophytic fungal partner; several orchid lineages have independently developed an exploitative life-style from this condition (Brundrett, 2002; 2004).

Such exploitative mycorrhizae are not known from the sporophytes of lycophytes and ferns, but gametophytes of Lycopodiaceae (Duckett & Ligrone, 1992; Winther & Friedmann, 2008), Ophioglossaceae (Schmid & Oberwinkler, 1994; Field et al., 2015c) and Psilotaceae (Duckett & Ligrone, 2005; Winther & Friedmann, 2009) are well known for being mycoheterotropic. These mostly involve AMF but recently Horn et al. (2013) reported the steady prevalence of basidiomycetes of the order Sebacinales (as found in orchid mycorrhiza and ECM) in gametophytes of *Diphasiastrum alpinum* (L.) Holub. This had been anticipated because basidiomycetes had already been documented as mycorrhizal endophytes for bryophytes (Pressel et al., 2010)

Mycorrhizae are species-specific regarding their phenotype (i.e., one fungus and one plant always engage in a specific type of interaction) but not regarding the taxa involved: Ferns can host a mixture of up to five different mycorrhizal fungi at the same time but with one usually dominating (Jansa et al., 2008), and one fungus can colonize different

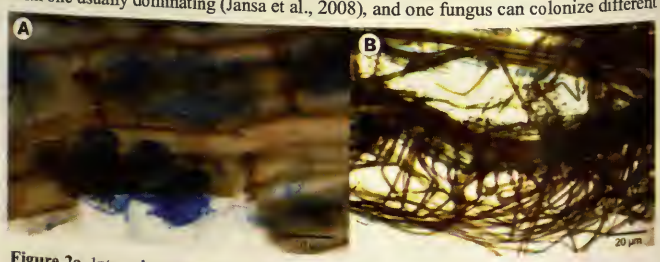

Figure 2a. Internal structures of arbuscular mycorrhiza (vesicles and arbuscules, lower ones partially released from cell due to preparation) in the root cortex of the tree fern *Cyathea tortuosa* R.C.Moran from Ecuador (Prov. Napo, 500 m) (20 x). **Figure 2b.** The roots of a typical non-mycorrhizal plant with pronounced root hair formation, represented by *Elaphoglossum castaneum* (Baker) Diels from Ecuador (Prov. Napo, 2000 m). (10 x) Photos Ramona Güdel.

plant species (Gemma et al., 1992; van der Heijden et al., 2015).

The true symbiotic nature of a fungal association can only be confirmed by physiological experiments aiming at the flow of nutrients (e.g., Jurkiewicz et al., 2010). As this has not been done for any fern yet, it is uncertain whether most observed associations are really symbiotic or functionally neutral (Brundrett, 2004; 2009). As Glomeromycota are fully dependent on the symbiosis and only known to occur independently from a host plant when they are dormant spores (Brundrett, 2009), it seems likely that a symbiotic relationship is involved in most cases but not necessarily with the roots in which they are found. Under high inoculum pressure in the substrate, typical non-mycorrhizal taxa may harbor AMF as neutral endophytes while the same mycelium probably forms a true mycorrhiza with a typical host plant nearby (Lekberg et al., 2015). Similarly, some typical non-mycorrhizal taxa have been found to be able to host AMF under nutrient deficiency (Brundrett, 2009). Furthermore, a low presence of fungi in the roots must not necessarily imply a low physiological activity between both partners. The categorization into obligate and facultative mycorrhizal plant species can only be evaluated in controlled experiments, e.g., by establishing sterile cultures of both partners and later re-inoculation (Pearson & Read, 1973), and not by visual estimation alone.

TAXONOMIC DISTRIBUTION OF MYCORRHIZAE

The mycorrhizal status is regarded to be ancestral among ferns (Zhao, 2000; Wang & Qiu, 2006), as is likely for all land plants (Pirozynski & Malloch, 1975; Strullu-Derrién et al., 2014; Field et al., 2015a).

The scant reviews of fern mycorrhizae have focused on the sporophyte and have come up with highly diverging results regarding the general presence of fungal symbionts as well as the distribution among the different groups. Newman and Reddell (1987) found 87% to be always mycorrhizal, 7% facultative, and 6% not mycorrhizal (based on 180 fern species), which is within the range of the values found for angiosperms (Brundrett, 2009). Others reported 75% of the studied fern species to have AM (Gemma et al., 1992). Zhao (2000) found only 33% of 256 species from China to be mycorrhizal (17% obligate + 16% facultative), and similarly Moteetee et al. (1996) reported 36% of the species to be mycorrhizal. Cooper (1976) found 100% of the investigated ferns to harbour mycorrhiza, but the sampling included only terrestrials and low epiphytes from humid subtropical to southern temperate forest, i.e., conditions that foster fungal growth. On the other extreme, Lesica & Antibus (1990) focused on epiphytes and found no mycorrhiza in the 12 investigated species. Wang & Qiu (2006) found 52% of all species and 92% of all families to harbour AMF. Brundrett (2009) summarized only more recent reports on mycorrhizae that he could trust, but contrary to his detailed summary on spermatophytes, he could not give an exact evaluation for ferns.

Lehnert (2007) used all available data on fern mycorrhiza worldwide starting from Boullard (1958, 1979), and evaluated simple presence/absence of mycorrhizal colonisations in three classes (aseptate fungi = AMF; septate fungi = DSE/ascomycetes; unspecified mycorrhiza) in 675 taxa (ca. 6% of the global diversity; Smith et al., 2006). The observed average of 62% for fungal colonisation lies in the middle of the range of previous reports for ferns but is lower than the values for seed plants (Brundrett, 2009). AMF are dominant among the fungal symbionts with 66%, whereas the remaining 34% are made up of ascomycetes, DSE and unspecified mycorrhizations. Across the phylogeny at the family level (sensu Smith et al., 2006), below average mycorrhization (≤62%) was found among several families of derived Polypods (non-grammitid

Polypodiaceae 23%, Tectariaceae 25%, Aspleniaceae 45%) but other families of the Polypods such as Davalliaceae and Onocleaceae had 100% mycorrhization. Vice versa, among the other leptosporangiate ferns, several families had below average mycorrhization rates (Anemiaceae 50%, Gleicheniaceae 48%, Cyatheaceae 53%). Among the eusporangiate lineages, only the Equisetaceae showed low mycorrhization (22%) whereas the remainder had average to high values (Psilotacae 67%, Marattiaceae 91%). Families largely restricted to aquatic habitats showed low (Isoetaceae; one of two samples) or no (Marsileaceae, Salviniaceae) fungal colonization. Mycorrhizal epiphytes were found mainly among grammitid ferns (84% of epiphytes and 74% of all species mycorrhizal), Hymenophyllaceae (76% of epiphytes and 76% of all species mycorrhizal) and Dryopteridaceae (63% of epiphytes [mainly *Elaphoglossum*] and 62% of all species mycorrhizal). Interestingly, only 42% of the investigated sporophytes of Lycopodiaceae had mycorrhizae despite their predominantly mycoheterotrophic gametophytes (Winther & Friedmann, 2008).

Later substantial additions to the survey (Kessler et al., 2009; 2010b; 2014a; Zubek et al., 2010; Ogura Tsujita et al., 2013; Muthukumar & Prabha, 2012; 2013; Lara-Pérez et al., 2015) have increased the species count but have not significantly changed the originally found total average and ratios between the substrates (Lehnert et al., unpublished data).

A caveat to bear in mind when comparing many different reports is the often uneven approaches regarding evaluation and quantification of the presence of fungi, as has been pointed out for AMF by Brundrett (2009). However, considering that it is more likely that fungi present have been over-interpreted as symbionts rather than that true, functioning mycorrhizas have been overlooked, these numbers are more likely to drop than to rise after a thorough re-evaluation. Thus, the observed pattern that lycophytes and ferns have a below-average colonization rate compared with seed plants or land plants in general is expected to hold true.

A similar but even stronger uncertainty lies in the data supporting the mutualistic nature of these colonizations, which would allow them to be addressed undisputedly as mycorrhizae (Brundrett, 2002; 2009). Most reports used only light microscopical preparation techniques to investigate the presence of fungi, which render the sample unsuitable for futher ultrastructural and molecular studies (pers. obs. for ferns, but see Ishii & Loynachan, 2004). Even if obligately mycorrrhizal fungi abound in the roots, this does not necessarily mean that the partners interact physiologically (Lekberg et al., 2015). Electron microscopy may allow the larger classification of the fungus and could reveal whether the host cell responded more in a symbiotic way or if it just tried to reject and contain the penetrating fungus (e.g. Schmid & Oberwinkler, 1994; Schmid et al., 1995). So far such ultrastructural and/or genetic investigations of mycorrhizae in the sporophyte generation covered only 12 species of lycophytes (Duckett & Ligrone, 1992; Winther & Friedmann, 2007a; Rimington et al., 2015) and 35 species of ferns (Schmid et al., 1995; Schmid & Oberwinkler, 1996; Pazmiño, 2006; Winther & Friedmann, 2007b; 2009; Lehnert et al., 2009; Field et al., 2015c; Rimington et al., 2015), which represents only a small fraction (3.7 %) of the 1,287 species of lycophytes and ferns for which reports are available (ca. 11 % of the global diversity; Lehnert et al., unpubl. data)

LIFE-STAGE DISTRIBUTION OF MYCORRHIZAE

Mycorrhizal interactions with fern gametophytes are not as uniform as often stated (Mehltreter, 2010). With a few exceptions (Duckett & Ligrone, 1992), gametophytes of

Lycopodiaceae, Psilotaceae (Duckett & Ligrone, 2005) and Ophioglossaceae are achlorophyllous and mycoheterotrophic, meaning not only do they receive water and minerals but also carbohydrates from the fungi (Schmid & Oberwinkler, 1994). By this means, the gametophytes may tap into the carbon source of another, photoautotrophic host of the fungus (Harley & Harley, 1987; Horn et al., 2013), possibly even the parental sporophyte (Winther & Friedmann, 2008). The anatomy of these mycoheterotrophic gametophytes, which are tuberous and relatively thick textured (Winther & Friedmann, 2007; 2008; 2009), allows an easy colonisation by fungi, whereas across fern lineages with photoautotrophic gametophytes, we see a gradual reduction of size (especially thickness) and longevity along the phyletic sequence (Smith et al., 2006). Mycorrhization rates seem to follow this pattern.

The eusporangiate Marrattiaceae (Bower, 1923; Ogura-Tsuijita et al., 2013) and the basal leptosporangiate Osmundaceae, Plagiogyriaceae, Gleicheniaceae and Cyatheaceae (Ogura-Tsuijita et al., 2015) show relatively constant and high presence of AM fungi (58–97%) in the thick centre of the gametophytes. However, most leptosporangiate families have the common heart-shaped *Polypodium*-prothallium and offer only restricted space for fungal symbionts; accordingly fungal colonization is observed infrequently (e.g., Reyes-Jaramillo et al., 2005; Turnau et al., 2005; Muthukumar & Prabha, 2012) and most taxa are considered to be only facultatively mycorrhizal (Read et al., 2000). In leptosporangiate lineages with strongly dissected to filiform prothallia (e.g., some Hymenophyllaceae, grammitid Polypodiaceae), AM are not observed (Boullard, 1979).

Even if both generations in the life cycle are mycorrhizal, the sporophyte does not directly inherit the fungal partner from the gametophyte but has to acquire it anew from the substrate (Schmid & Oberwinkler, 1995), so that each generation can have a different assortment of fungal partners, although usually with a strong overlap (Winther & Friedmann, 2008).

HABITAT DISTRIBUTION OF MYCORRHIZAE

Among ferns, most studies have only considered selected species; whole fern communities have been studied only in Canada (Berch & Kendrick, 1982), China (Zhao, 2000), La Réunion (Kessler et al., 2010), and Ecuador (Kessler et al., 2014a). In general, the mycorrhization rate of soil-growing fern species is typically higher than that of epiphytic species (Gemma et al., 1992; Kessler et al., 2010). Thus, Lehnert (2007) reported putative mycorrhizal fungi mainly in terrestrial and saxicolous species (67% and 59%, repectively) but only in 53% of epiphytic species and in 9% of aquatic species. The percentage in epiphytes included a high presence of ascomycetes + DSE (67% of colonisations), whereas the remaining 33% of epiphytic mycorrhiza represented only 8% of the total of AMF colonisations in all lycophytes and ferns.

The low rate of mycorrhizal infections among epiphytes may be caused by either the fungi or the ferns. Glomeromycetes, in particular, are expected to have a lower colonization potential than fungi with air-borne spores (e.g., ascomycetes, basidiomycetes) because they produce spores subterraneously and require stable substrate conditions for growth and development (Zubek et al., 2010), thus being hardly suited for the dynamic canopy habitat (Janos, 1993). It has also been suggested that epiphytic ferns may be less dependent on mycorrhizae because they have special adaptations (e.g., drought resistance, leaf litter traps, thick storage rhizomes) that limit requirements for mycorrhizae (Mehltreter, 2010).

Among the ferns growing on the ground, there are also slight differences between

substrates, with those on well-developed soil and rocks having high levels of mycorrhization than those on sand – again a habitat that is unsuitable for fungal growth (Brundrett, 2009) – having fewer mycorrhizal fern species (Gemma et al., 1992).

A special case is provided by raw volcanic soils, especially on islands such as Hawai'i. It has been suggested that such soils are more easily colonized by nonmycotrophic or facultatively mycorrhizal fern species due to the paucity of fungal innoculum, perhaps facilitating later colonization of obligate mycotrophic ferns and angiosperms (Gemma & Koske, 1990; Gemma et al., 1992). This contrasts, however, with the regular presence of mycoheterotrophic gametophytes of *Psilotum* in volcanic soils (Holloway, 1938; Duckett & Ligrone, 2005) and observations on La Réunion, where the percentage of terrestrial fern individuals with mycorrhizae was higher on shallow, raw soils with high pH values, high base-saturation and low nutrient availability (Kessler et al., 2010). These contrasting results may be due partly to the fact that the Hawai'i studies were based on the species level, whereas the results from La Réunion are based on numbers of individuals.

Mycorrhization is absent to very rare in aquatic environments (Boullard, 1958; 1979; Lehnert et al., 2007; Brundrett, 2009), presumably reflecting the paucity of fungi in such environments. Furthermore, the benefits mycorrhiza could bring are no longer advantageous in a medium in which water and most nutrients are freely available and often in surplus, but – at least in the case of fully submerged plants – assimilation is hampered by lower CO_2 partial pressure and decreased light intensity. In some cases, amphibious species that grow both inundated and on dried-out soils are facultatively mycorrhizal, as found in some *Isoetes* (Beck-Nielsen & Madsen, 2001; Radhinka & Rodrigues, 2007). Likewise, species of *Equisetum* are non-mycorrhizal in wetlands, but commonly mycorrhizal in dry environments (Harley & Harley, 1987; Marsh et al., 2000; Read et al., 2000; Brundrett, 2002).

Focussing on climatic gradients, the degree of mycorrhization has been documented to decrease with elevation in Ecuador (Kessler et al., 2010). In addition to the commonly proposed fungus-oriented explanations based on reduced fungal growth at low temperatures (Read & Haselwandter, 1981; Olsson et al., 2004; Schmidt et al., 2008), these authors also proposed a fern-oriented one in that mycorrhization might decrease because the relative costs of allocating carbon to the fungal partner increase with elevation (where photosynthesis decreases: Kessler et al., 2014b) and possibly exceed the benefits of the fungal nutrient supply.

ECOLOGICAL EFFECTS OF MYCORRHIZATION IN FERNS

Based on work on seed plants, it is known that fungi provide plants with soil nutrients (especially PO_4), water, and other benefits (Blackwell, 2000; Wilkinson, 2001). In exchange, the fungi obtain organic C from the photosynthetic host plants (Smith & Read, 2008; Olsson et al., 2010), which allocate up to 20% of their net photosynthetic C to their fungal partners (Allen et al., 2003). The relative costs of this fungal C use have to be assessed in relation to the benefits derived from increased nutrient uptake, and presumably can be offset partly by higher rates of photosynthesis, if the plants are not light limited (Smith & Smith, 2011). In greenhouse experiments with potted plants, mycorrhizal fungi have been shown to increase leaf tissue nutrient concentrations, most importantly those of P (Stribley et al., 1980; Smith & Smith, 2011).

For ferns, very few data are available, and contrary to seed plants there are no greenhouse experiments. In an early study, Cooper (1976) showed that mycorrhizal plants

of the facultatively mycorrhizal *Pteridium aquilinum* (L.) Kuhn in New Zealand had stronger growth than non-mycorrhizal individuals. More recently, it has been shown both on La Réunion and in Ecuador that terrestrial mycorrhizal fern species are locally more abundant than those lacking mycorrhizae (Kessler et al., 2010; 2014a). For example, on La Réunion, the 78% mycorrhizal species made up 98% of all fern individuals. This suggests a clear ecological advantage provided by mycorrhizae to ferns.

On the other hand, a study in Ecuador found that fern species with mycorrhizae had lower relative biomass increment per year than those without mycorrhizae (Kessler et al., 2010), suggesting a high C cost of mycorrhization. Even more surprisingly, non-mycorrhizal fern species had significantly higher concentrations of N, P, Mg, and Ca in their leaves. Negative growth effects of mycorrhization have previously been documented in a number of cases among seed plants (e.g., Johnson et al., 1992; Smith & Read, 2008; Veiga et al., 2011). These often reflect the parasitic nature of mycorrhizal fungi in situations in which the nutritional benefits for the plant do not outweigh the C loss to the fungi (Johnson et al., 1992; Karst et al., 2008).

The very sparse data available until now thus provide evidence for benefits of mycorrhization in ferns as well as for negative effects. While this may initially be surprising, in fact it makes sense if we consider that not all plant species have mycorrhizae (Brundrett, 2009), even if they do not grow under special habitat conditions that limit fungal growth such as aquatic or epiphytic environments. If we further bear in mind that the ancestral state is most likely the presence of mycorrhization, then the 33% of terrestrial and 47% of epiphytic fern species lacking mycorrhizae (Lehnert, 2007) must have lost them over evolutionary times, suggesting that there must be a benefit of losing mycorrhiza. It thus appears that there is a fine balance between positive and negative effects of mycorrhization among land plants in general and ferns in particular. It is much too early to speculate under which conditions this balance switches either way, especially considering that the balance is likely to be not simply determined by a nutrient-carbon trade-off but also by water relations and the influence of symbiotic fungi on parasitic or pathogenic fungi and other biotic interactions.

OPEN QUESTIONS

We conclude this overview of what is known about mycorrhizae in ferns with a series of questions that readily develop from the above text. This list is certainly incomplete, but it may offer some guidelines as to what we would like to know to better understand the role of mycorrhization in ferns and lycophytes:

- Are all visually detectable fungal associations of ferns truly mutualistic? Most of the records are based on light microscopical screenings only and await further microstructural and molecular conformation. Until now, true mycorrhizae with mutual benefits have been confirmed only for lycophytes and basal fern lineages and involve only Glomeromycota and Mucoromycotina.
- Why is the overall degree of mycorrhization lower among lycophytes and ferns (and liverworts) than among seed plants? Does this reflect some basic physiological difference between spore-bearing and seed-bearing vascular plants, e.g., in water use efficiency (Brodribb et al., 2009; Watkins et al., 2010) that tips the balance more in the direction of non-mycorrhization in ferns?
- What is the role of mycorrhization in ferns that are very difficult to cultivate or transplant, such as Gleicheniaceae, Lycopodiaceae and grammitids (Page, 2002)?
- For ferns with facultative or variable mycorrhization, does the degree of

mycorrhization vary with ecological conditions?
- Are there implications of mycorrhizal associations in ferns for insect herbivory or other ecological interactions?

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A SHORT BIOGRAPHY OF THE AUTHORS

Michael Kessler was born and grew up in Peru where he spent much of his childhood chasing birds across the forest and mountains of the country. He studied biology at the University of Göttingen, Germany from 1986 onwards, culminating with his PhD thesis on the taxonomy, ecology, and biogeography of the high-Andean tree genus *Polylepis* (Rosaceae) in 1995. He then shifted his focus to the plant diversity of tropical montane forests, and, inspired by the work of Hanna Tuomisto in Amazonia, picked ferns as a study group. Over the years, ferns have become the main focus of his work, with research mainly on diversity patterns and ecology, but also numerous taxonomic studies, especially on Bolivian ferns. Since 2008, he has worked as scientific curator of the botanical garden and researcher at the University of Zurich, Switzerland. Currently, his fern work is mainly concerned with understanding the evolutionary and ecological processes that determine the richness and composition of fern assemblages, involving fieldwork in, e.g., Mexico, the Andes, Uganda, Indonesia, and New Guinea. Other projects involve studies on the diversification of bromeliads and palms in the neotropics and the flora of the canton of Zurich in Switzerland.

Marcus Lehnert was born on 1 October 1975 in Neutstadt/Ostholstein, Germany. He attended Göttingen University, where he received his Diplom (M.S. equivalent) in 2002 and his Ph.D. in 2007. His research was based first at the Albrecht-von-Haller Institute for Plant Sciences, Göttingen (2000–2007), with interludes at the Instituto de Ecología, Universidad Mayor de San Andres, La Paz, Bolivia (2002–2003) and the University of Califomia, Berkeley (2006–2007). From 2008-2012, he was employed as a Postdoctoral Researcher in the Botany Department of the State Museum for Natural History in Stuttgart. Since 2013 he has been a research assistant at the Nees Institute for Plant Biodiversity, University Bonn. His research interest focuses on the taxonomy, phylogeny, and floristics of ferns but also includes mycorrhiza, general biogeography, and the systematics of several angiosperm families. For his fieldwork, he has visited among others Puerto Rico, Panama, Peru, Argentina, Brazil, and several times Ecuador, Colombia, Bolivia and New Guinea. Marcus Lehnert is currently working on a large-scale projects focusing on the use of DNA barcoding for the rapid assessment of biodiversity (Accelaration of Biodiversity Assessment—ABA Ecuador and German Barcode of Life-GBoL). He has contributed his taxonomical expertise on scaly tree ferns (Cyatheaceae) to floral projects like "Catálogo de las Plantas Vasculares del Cono Sur" and "Ferns of Bolivia."

THE FERN FAMILY PTERIDACEAE IN TURKEY

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ABSTRACT

The last comprehensive study of Turkish Pteridaceae was made over 50 years ago. In this study the family Pteridaceae in Turkey is reviewed according to recent taxonomic and nomenclatural changes and a full description, synonyms and distribution information are given for each taxon and a key provided.

INTRODUCTION

A generic classification of cheilanthoid ferns (Pteridaceae) has eluded taxonomists for more than 200 years (Grusz & Windham, 2013). Several taxonomic and nomenclatural updates have been made in recent decades, based on morphological and molecular methods (Gastony & Rollo, 1995; Sanchez-Baracaldo, 2004; Zhang et al., 2005; Smith et al., 2006; Kamau, 2007; Schuettpelz et al., 2007; Windham et al., 2009; Grusz & Windham, 2013; Schneider et al., 2013; Abotsi et al., 2015). The current family diversity is about 1000 species distributed in 53 genera (Schuettpelz et al., 2007; Christenhusz et al., 2011).

The last comprehensive study of Turkish Pteridaceae was made over 50 years ago (Henderson, 1965) for the *Flora of Turkey*. A major project was recently initiated to illustrate and describe the flora of Turkey in the Turkish language and the first volume of *Resimli Türkiye Florası* [*Illustrated Flora of Turkey*] was published by Güner and Ekim (2014). The second volume, which will include the family Pteridaceae, is scheduled for publication in 2016. The aim of the present study has been to review Turkish Pteridaceae according to recent taxonomic and nomenclatural changes and to provide descriptions and distributions for each taxon. It is based on recent literature on Pteridaceae (e.g. Nardi & Reichstein, 1985; Benlioğlu et al., 1997; Kaynak et al., 2008; Christenhusz et al., 2011; Greuter & Raab-Straube, 2012; Jessen et al., 2012; Güner et al., 2012), and on herbarium specimens from Ankara University Faculty of Pharmacy (AEF), Ankara University Faculty of Science (ANK), Natural History Museum, London (BM), Royal Botanic Garden Edinburgh (E), Geneva (G), Gazi University Faculty (GAZI), Hacettepe University (HUB), Istanbul University Faculty of Pharmacy (ISTE) and Royal Botanic Gardens, Kew (K). All specimens listed below are from E, except where indicated otherwise.

PTERIDACEAE E.D.M.Kirchn., Schul-Bot.: 109 (1831).
Synonym: *Adiantaceae* Newman, Hist. Brit. Ferns: 5 (1840), *Sinopteridaceae* Koidz., Acta Phytotax. Geobot. 3: 50 (1934). *Cryptogrammaceae* Pic.Serm., Webbia 17: 299 (1963). *Cheilanthaceae* B.K.Nayar, Taxon 19: 233 (1970).

Key for Turkish Pteridaceae taxa

1. Fertile and sterile leaves or pinnae conspicuously dimorphic **2**
1. Fertile and sterile leaves or pinnae not, or weakly dimorphic **4**
2. Annual, sori on the lower surface of the leaf, indusium absent ..... ***Anogramma leptophylla***
2. Perennial, sori marginal, covered by the recurved leaf margin **3**
3. Lamina of sterile leaves up to 16 cm long, ovate to deltoid-ovate, spores <60µm long ..... ***Cryptogramma crispa***
3. Lamina of sterile leaves up to 7 cm long, broadly deltoid, spores >60µm long ..... ***Cryptogramma bithynica***
4. Pinnules fan-shaped; petiole blackish, glabrous, fine and wiry ..... ***Adiantum capillus-veneris***
4. Pinnules not fan-shaped; petiole not as above **5**
5. Fronds pinnate to pinnatisect, weakly dimorphic **6**
5. Fronds 2-pinnate, not dimorphic **7**
6. Leaves 1-pinnate, lanceolate, >10 pinnae pairs ..... ***Pteris vittata***
6. Lower pinnae pinnatisect, frond ovate-triangular, with 7 or fewer pinnae pairs ..... ***Pteris cretica***
7. Underside of pinnules glabrous or with glandular hairs **8**
7. Underside of pinnules densely covered with scales or eglandular hairs **10**
8. Pseudoindusium entire, frond sparsely glandular below ..... ***Allosorus tinaei***
8. Pseudoindusium ciliate, frond eglandular below **9**
9. Pseudoindusium narrow, with dense long marginal hairs, spores <45 µm long ..... ***Allosorus persicus***
9. Pseudoindusium broad, irregular, with short cilia, spores >45 µm long ..... ***Allosorus acrosticus***
10. Upper surface of pinnules glabrous ..... ***Paragymnopteris marantae***
10. Upper surface of pinnules white, woolly ..... ***Cosentinia vellea***

Adiantum L., Sp. Pl. 1094 (1753).

Short-creeping, scaly rhizome. Fronds dense or sparse; stipe dark brown or black shiny. Pinnae fan-shaped, without a midrib, sori borne on reflexed marginal lobes of lamina.

A. capillus-veneris L., Sp. Pl. 2: 1096 (1753).

Synonyms: *Adiantum capillus* Sw., J. Bot. (Schrader) (2): 83 (1801). *A. formosum* R.Br., Prodr. Fl. Nov. Holland 155 (1810). *A. schaffneri* Fourn., Bull. Soc. Bot. France 27: 328 (1880). *A. modestum* Underw., Bull. Torrey Bot. Club. 28: 46 (1901). *A. michelii* Christ, Bull. Geogr. Bot. Mans. 12 (1910).

Lectotype: Herb. Linn. 1252.9 (LINN)!

Rhizome densely covered with shiny, narrow lanceolate scales. Fronds bipinnate, (5–)15–30(–45) × (1.5–)4–6(–10) cm, glabrous; stipe (1.5–)8–12(–20) cm long, brown or black, shiny, glabrous. Pinnae 2–7 × 1–4 cm with stalk 0.3–3 cm long. Pinnules fan-shaped, (0.7–)1–2(–3.5) × (0.7–)1–2.4(–3) cm, cuneate at base, without midrib, 2–8 lobed with stalk (1–)2–5(–16) mm long. Sori borne on reflexed marginal lobes of lamina.

Habitat: In crevices of limestone and serpentine or tufa and base-rich soil on shady banks, 1–1000 m.

Distribution in Turkey:

Adana: Feke; Göksu gorge, 800 m, 09.vii.1952, *Davis* 19855!

Antalya: Kemer, Sumakşehiri Deresi, kalkerli G. Deresi değil vadisi, *P. nigra-C.*

sempervirens ormanı 500-700 m, 06.x.1977, *H. Peşmen* 3569 & *Ş. Yıldırımlı* HUB 36734! Alanya, 120 m, 04.viii.1982, *Ş. Yıldırımlı* 4451 HUB 36732! Aksu, Düden Çağlayanı, 06.ix.1988, *Ş. Yıldırımlı* 11596 HUB 36736!

Artvin: Çoruh gorge, between Yusufeli and Artvin. 600 m, 01.viii.1966, *Davis* 47690! Demirkent nahiyesi, zwischen Tortum Gölü und Artvin, 620 m, 03.viii.1973, *F. Holtz, P. Hanel & T. Kesercioğlu* 991! Hopa, Kemalpaşa-Sarp arası, denize dik kayalıklar, 0-50 m, 19.v.1985, *Ş. Yıldırımlı* 7898 HUB 36740!

Bursa: Uludağ, 25.vi.1946, *A. Yılmak*!

Denizli: 13.vii.1947, *Davis* 13263! Pamukkale, 16.x.1980, *Ş. Yıldırımlı* HUB 36728!

Düzce: Akçakoca, Edilli Köyü, kıyı kumul, orman, 50 m, 29.ix.2001, *A. Doğru Koca* 1489 (HUB)!

Hatay: Dörtyol, Kuzuculu to Bülke on forest road, 1000 m, 04.iv.1965, *M.J.E. Coode & B.M.G. Jones* 416! Valley above Dörtyol, south bank, north facing, boulder clay and serpentine, 150 m, 12.viii.1969, *J. Darrah* 623! Valley above Yeşilkent, 305 m, 11.viii.1969, *J. Darrah* 505! Samadağ, Çevlik, Vespasiyanus ve Titus Tüneli boyunca, Beşikli mağarası ve taşlık maki, 10-150 m, 04.ix.1990, *Ş. Yıldırımlı* 13926 (GAZI)! Antakya, Harbiye, Şelale, 180 m, 25.iv.1978, *M. Coşkun* 332, *B. Şener & F. Ilisulu* AEF 6353! Kırıkhan, Delibekirli, nemli kayalıklar, 500 m, 21.iv.1977, *M. Koyuncu* AEF 5668! Musa Dağı, nemli yerlerde, 14.iv.1967, *Y. Akman* ANK 7943!

İçel: Kanlıdivane, 23.iv.1974, H. Peşmen & S. Erik HUB 36733! Anamur, Nasrettin Köyü üstü, 21.iv.1975, *M. Koyuncu* & *M. Coşkun* AEF 4854!

İzmir: Kemalpaşa, Next to a stream in shady ravine in macchia in the foothills of Nif Dağ, 06.vi.1966, *R. Alava & C. von Regel* 5040!

Karamanmaraş: Andırın; 8 miles South of Çatak, 800 m, 17.v.1965, *M.J.E. Coode & B.M.G. Jones* 1147! Süleymanlı, Akdağ, nemli dere içi, 1500 m, 24.vii.1977, B. Yıldız 1555 HUB 36731!

Konya: Ermenek, Kazancı kasabası, Yeşilköy, Göksu Nehri boyunca, 700 m, 12.x.1983, *H. Sümbül* 2536 HUB 36730! Ermenek, Göktepe Kasabası, Darcın Köyü, Ayaşlı mevkii, Göksu Nehri Boyunca, 600 m, 15.ix.1983, *H. Sümbül* 2477 HUB 36729!

Malatya: Pütürge, Ferikhan Köyü, dere kenarı, ca. 650 m, 06.v.1981, *Y.Altan* ANK 1252!

Manisa: Manisa Dağı (Spil), Karaçay boyunca, 150-450 m, 23.iv.1984, *Ş. Yıldırımlı* 6014, HUB 36739!

Mardin: Hessana at S foot of Cudi Dağ, 900 m, 10.v.1966, *Davis* 42776! Kasrık Boğazı, 11 km from Cizre to Şırnak, shady river bank near bridge, 400 m, 7.v.1966, *Davis* 42641! Dargeçit, Çelik Köyü, Umutlu mezrası, kaya üzeri, 520 m, S. Aslan 3308 et al. (GAZI)!

Muğla: 13 km South of Köyceğiz, by road to Dalyan, just east of the village of Tepearası, 10–20 m, 19.v.1990, *R. Lampinen* 7492! Köyceğiz, Yangı Köyü Yangı Deresi, kalkerli, sarp derin vadi, kazmofit, 22.iii.1981, *A. Güner* 8421 et al. HUB 36725! Fethiye, Katrancı Adası, 0-20 m, 21.v.2011, Z. Aytaç 9830 (GAZI)! Boyobası Köyü, Saklayıcı mevkii, şistik arazi, nemli çakıllık, 120 m, 18.ii.1991, *A. Güner* 8103 et al. (GAZI)! Yatağan-Milas arası, su kenarı, 21.v.1970, *N. Tanker* AEF 4851!

Rize: Rize-Çayeli arası, c. 10 m, yol kenarı, 19.viii.1985, *A. Güner* 6848 & *M. Vural* HUB 36726! Pazar-Hemşin, nemli kaya üzerinde, 150 m, 19.vi.1984, *M. Vural* 2913 HUB 36735!

Sakarya: Adapazarı; Karasu to Söğütlü, 30 m, 07.viii.1962, *Davis* & *Coode, D.* 39101!

Samsun: Samsun'un 10 km doğusu, asfalt kenarı, 10 m, 12.ix.1964, *H. Kayacık & G. Elçin* 2211! Seaside cliffs, 3 miles east of Samsun, 10 m, 19.v.1963, *Tobey* 133!

Sinop: On south wall of bath, 10 m, 23.iv.1966, *Tobey* 1624! Ayancık, Bakırlı Köyü yol

ayrımından Akgöl'e 2 km, 15.ix.2009, *A. Dönmez* 16205 & *Z. Uğurlu* (HUB)!
Şanlıurfa: Urfa-Gaziantep c. 1 km from Urfa, 600 m, 11.ix.1956, *McNeill* 794!
Trabzon: Maçka, 24 km south of Trabzon, 250 m, 28.vi.1960, *Stainton & Henderson* 5895!
General Distribution: Widespread in temperate and subtropical regions of the New and Old World, absent from South America.

Anogramma Link, Fil. Spec. 137 (1841).
Small, annual, delicate plants with short rhizome. Prothallus perennial and mostly persistent. Fronds dimorphic, mature fertile fronds bi-tripinnate, pinnae simple. Sori linear, indusium absent.
A. leptophylla (L.) Link, Fil. Spec. 137 (1841).
Synonyms: *Polypodium leptophyllum* L., Sp. Pl. 2: 1092 (1753); *Acrostichum leptophyllum* Lam. & DC., Fl. Franc. (de Candolle & Lamarck), ed. 3. 2: 565. (1805); *Grammitis leptophylla* (L.) Sw. Syn. Fil. (Swartz) 23, 218, t. 1. f. 6. (1806); *Gymnogramma leptophylla* (L.) Desv. in Berl. Mag. 5: 305 (1811); *Hemionitis leptophylla* Lag. Gen. Sp. Pl. (Lagasca) 33: (1816).
Lectotype: Herb. Linn. 1251: 56 (LINN)!
Plant delicate, up to 15 cm high, annual, with short rhizomes. Prothallus perennial, reniform, bilobed, 7–10 mm long. Fronds yellow-green, glabrous, young fronds reniform and 3–5 lobed, mature fronds bipinnate 5–15 ×1–1.5 (–2) cm, stipe glabrous 2.5–7 cm long, dark brown-black below and yellow-green above. Pinnae glabrous, 0.5–2 × 0.5–1 cm, dichotomously veined, pinnae stipe 1–2 mm. Pinnule mostly bilobed or lanceolate. Sori linear along veins; no indusium.
Habitat: Dry metamorphic rocks or moist shady serpentine rocks, 30–1000 m.
Distribution in Turkey:
Adana: Feke; Senean dere between Gurumze and Suphandere, 1000 m, 01.vii.1952, *Davis* 1961, *Dodds & Çetik*!
Antalya: Rocks near the sea, 12.iv.1955, *H. Walter* 3891! Side, c. 40 m, 19.v.1994, *K. Karamanoğlu, M. Koyuncu & M. Coşkun* AEF 16! Kemer, Kesmeboğaz, kalker kayalığı, 200 m, 25.iii.1978, *H. Peşmen* 3649 & *B. Yıldız* HUB 36798! Kemer, Beycik-Delikin Tepesi arası, 500-700 m, kalker kayalığı, *P. brutia* maki karışık ormanı, 28.iv.1980, *H. Peşmen* 4818 HUB 36796!
Hatay: Dörtyol; Rabat, vertical serpentine flush, c. 100 m, 05.v.1965, *M.J.E. Coode & B.M.G. Jones*!
Isparta: Ş.Karaağaç, Kızıldağ Milli Parkı, Kuzgu Tepe, kaya üzeri, 1350 m, 24.vii.1994, *B. Mutlu* 1084 HUB 36794!
İçel: Anamur, Nasrettin Köyü üstü, pınar civarı nemli yerlerde, 250 m, 21.iv.1975, *M. Koyuncu & M. Coşkun* HUB 36797!
Kastamonu: Taşköprü, Kayabaşı Köyü yukarısı, yangın kulesine tırmanış, dağ bozkırı, *P. nigra-P. sylvestris* açıklığı, 04.viii.2010, *A. Dönmez* 17533 & *Z. Uğurlu* (HUB)!
Muğla: behind Marmaris, 50–100 m, 14.iv.1965, *Davis* 41407! Marmaris, On soil amongst rocks in ravine forest near Hotel Lidya, 06.v.1984, *E.C. Wallace*! Marmaris, Pinetum brutiae, on serpentine, 30 m, 24.iii.1956, *Davis* 25258 & *O. Polunin*! Ortaca, Dalyan, Gökbel Köyü, Kızıl Çam ormanı, kalkerli arazi, 100-150 m, 14.iv.1991, *A. Güner* 8622 et al. HUB 36795! Köyceğiz, Ekincik Köyü, Sandallı tepe, makilik, kalkerli arazi, 10-500 m, 19.v.1991, *A. Güner* 9097, *M. Vural & H. Şağban* HUB 36799! Ortaca, Dalyan, Marmarlı çevresi, makilik arazi, 30 m, 19.iv.1991, *A. Güner* 8918 et al. (GAZI)!

General Distribution: Mediterranean area, Switzerland, W. France and Channel Islands, Crimea, N. America; scattered to S. Africa, India and Australasia.

Allosorus Bernh., Neues J. Bot. 1(2): 36 (1805).
Rhizome short-creeping or tufted. Fronds persistent, bipinnate; stipe wiry. Sori terminal on veins, protected by a linear pseudoindusium, a recurved and modified leaf margin.
A. acrosticus (Balbis) Christenh. Willdenowia 42(2):284. (2012)
Synonyms: *Pteris acrostica* Balb. Elenco 98. (1801). *Cheilanthes acrostica* (Balbis) Tod. Giornale de Scienze Naturali ed Economiche de Palermo 1(10): 215. (1866).
Lectotype: "Polypodium ilvense Bell. / puto esse potius novam plantam pteridis genus" [Balbis's handwriting] / "est Polypodium fragrans L." [not Balbis's handwriting] (TO). Four plants. (see Nardi & Reichstein. 1985).
Plant up to 20 cm, rhizome brown and covered with long linear, reddish brown scales. Fronds bipinnate, 3–20 × 1–2.5 cm, glabrous, green; stipe dark brown-black 1.5–11.5 cm with a few scales. Pinnae 0.5–3 × 0.3–1 cm, stalk sessile, 1–3 mm long at end of the fronds. Pinnule 0.5–2 mm broad, without midrib. Sori many; pseudoindusium broad, irregularly lobed, ciliate.
Habitat: Crevices in limestone rocks, sea level up to 500 m.
Distribution in Turkey:
Antalya: Antalya-Burdur yolu, 33. km, 12.iv.1965, *A. Baytop & T. Baytop* 7926! Çarma Dağ, 700ft., 17.vi.1958, *E.R.B.Little*! Aspendos Amphitheatre near Serik, c.50m. 02.viii.1975, *C.R.Fraser Jenkins 4573*. BM! Kemer Küçükburun, kasabanın doğusundaki küçük yarımada, *P. brutia* ormanı, 20 m, 21.iii.1949, *H. Peşmen 4150 & A. Güner* HUB 36705! Kemer, Kesmeboğaz, kalker kayalığı, 300 m, 25.iii.1978, *H Peşmen & B. Yıldız* HUB 36707! Kaş, Kekova, Alan-Kale Mahallesi, kalker kaya çatlağı, 10-20 m, 14.ii.2009, *Z. Aytaç* 9286 *& H. Duman (*GAZI*)*! Alanya, Hacımemetli Köyü, Bağderesi, 200 m, 21.iii.1993, *M. Koyuncu* 9595 *& H. Duman (*AEF*)*!
Aydın: Söke Milet haraberleri, anfitiyatro duvarları üzerinde, 10.v.1965, *Kayacık & Yaltırık* ISTO 3545!
Balıkesir: Ayvalık, Pınar Adası, 60 m, 10.v.1996, *K. Alpınar* ISTE 71797!
Çorum: Alacahöyük Köyü, 01.vii.1995, *U. Sönmez* ISTE 68382!
Denizli: Mt. above Pamukkale (Hierapolis) hot springs near Burdur, rock crevice, dry place on vertical earth bank with *C. persica* and *Selaginella denticulata*, 1000-1150m, 16.v.1973, *Betty E.G. Molesworth Allen 8102*. BM!
Hatay: Castle of Payas, near Dörtyol, sea level, 03.iv.1965, *M.J. Coode & B.M.G. Jones* 394! Kırıkhan to Hamam, c. 100 m, 06.v.1965, *M.J. Coode & B.M.G. Jones* 533!
İçel: Işıktepe (Seydüşıh) Köyü üstü, maki, kalker anakaya, 150-500 m, 19.iv.1985, *Ş. Yıldırımlı* 7594 HUB 36723! Mersin, Anamur çevresi, 09.v.1972, *M. Koyuncu* HUB 36697! Dibek Mağarası girişi, Cennet-Cehennem, 09.xi.1973, *A. Baytop & E. Tuzlacı* ISTE 27072!
İzmir: Schuth hinter Friendhof von Ahmetbeli, ca. 100 m, 19.iii.1966, *G. Bocquet* 1523! Selçuk harabeleri, 09.iv.1971, *A. Baytop & T. Baytop* ISTE 19112!
Konya: Bucakkışla, Dede Dağı, Kayalık, kurak yamaçlar, maki, ca.580 m, 25v.1979, *M. Vural* 1873 GAZI)!
Muğla: ca. 4 km nw Muğla. Felsen in der Macchie, 03.iv.1974, *K. Lewejohann* (Tu-74-137) *& F. Holtz*! Dereköy, between Marmaris and Muğla, 10 m, 26.iii.1956, *Davis* 25395 *& O. Polunin*! BM! Fethiye, 30 m, 27.iii.1956, *Davis* 25421 *& O. Polunin*! BM! Kişle to Kozağaç (Milas-Yatağan), 550 m, 13.iv.1965, *Davis* 41056! Marmaris, Söğüt to

Bozburun, sea level–50 m, 15.iv.1965, *Davis* 41168! Dalyan-Sülüngür Gölü, Ortaca arası, 100-200 m, 14.iv.1981, *A Güner* 8571 et al. (HUB)! Bodrum, Türkbükü-Bodrum, 200-500 m, 15.iii.1984, *Ş. Yıldırımlı* 5883 HUB 36696! Köyceğiz, Çandır Köyü, Kaunos Harabeleri, duvar arası, 80 m, 08.xi.1991, *A. Güner* 10323 (GAZI)! Köyceğiz, Yangı Köyü, Yangı Deresi, sarp ve derin vadi, kalkerli yamaçlar, 60-80 m, 24.v.1981, *A. Güner* 8324, *M. Vural & H. Şağban* (GAZI)!

General Distribution: From Mediterranean area to West Himalayas.

Note: There has been confusion in the past between *Allosorus acrosticus* and *A. pteridioides* (Reichard) Christenh. (see Nardi & Reichstein, 1985). *Allosorus acrosticus* is a tetraploid taxon, whereas *A. pteridioides* is diploid. This latter has a more western Mediterranean distribution and, so far, has not been recorded for Turkey, although there are records from Cyprus and Jordan in BM and from Syria and Palestine in E, and it may have been overlooked in Turkey. The two taxa have similar morphology but can be distinguished; *A. acrosticus* has a pseudoindusium with ciliate margins, with scales on rachis and costae, whereas *A. pteridioides* has pseudoindusium entire, and rachis and costae are ± glabrous.

A. persicus (Bory) Christenh. Willdenowia 42(2): 284 (2012).

Synonyms: *Notholaena persica* Bory in Bélanger & al., Voy. Indes Or.: 23 (1833); *Cheilanthes szovitsii* Fisch. & Mey. apud Hohen. in Bull. Soc. Nat. Mosc. 1838 No. 3: 241 (1838); *Cheilanthes persica* (Bory) Kuhn in Bot. Zeitung (Berlin) 26: 234 (1868).

Lectotype: [Iran] La Perse, parmi les rochers, 1821, *C. Bélanger s.n.* P00607931 (P)!

Plant up to 20 cm, rhizomes covered densely in narrow dark brown-black scales. Fronds bipinnate, 3–16 × 1–4 cm, green and glabrous above and with brown scales on rachis and costae, eglandular; stipe 1–8 cm, covered with dark brown-black and narrow lanceolate or linear long brown hairs. Pinna (0.3–) 1–3 × 0.2–2 cm; pinna stalk very short c. 1 mm, pinnules lobed, lobes lancolate. Sori many; pseudoindusium narrow, with many long marginal hairs that cover the lower surface of the segment.

Habitat: Shady crevices in limestone or metamorphic rocks, 200–2300 m.

Distribution in Turkey:

Adana: Feke, Sencan Dere between Belenköy and Suphandere, 1000 m, 02.vii.1952, *Davis* 19586A, *Dodds*, *Çetik*! Kozan, (Anti-taurus), 300 m, 12.iv.1957, *Davis* 26614, *Hedge*! Osmaniye-Yarpuz, 15 km e Osmaniye, 800 m, 29.iv.1986, *M. Nydegger* HUB 36695!

Ankara: mamak, Kıbrıs Köyü vadisi, Dipsiz gölü mevkii, kaya çatlağı, gölgeli yerler, 1000-1100 m, 26.vi.2005, *S. Arslan* 2352 (GAZI)!

Antalya: Kumluca, Sazak Koyu, kalker kayalığı, 40 m, 29.iv.1980, *H. Peşmen* 4876 HUB 36704! Konyaaltı, 10 m, 23.v.1977, *M. Koyuncu & M. Coşkun* HUB 36703! Koslu Dere, n.of Bozburun Dağ, 1200 m, 27.vii.1949 *Davis* 15754.

Aydın: 3 km westlich Ortaklar, Abangh am Ovacık Dag oberhalb der Strasse Selçuk-Ortaklar, 200 m, 22.v.1966, *G. Bocquet* 2472! Söke, piriyen, 400 m, 30.v.1972, *N. Tanker*, AEF 17!

Denizli: Bozdağ above Geynam yaila, 16.vii.1947, *Davis* 13432!

Erzincan: Kemaliye, Yaka Köyü, Sazak deresi, kazmofit, 850-1000 m, 18.xi.1980, *Ş. Yıldırmlı* 4186 HUB 36708!

Isparta: Ş. Karaağaç, Kızıldağ Milli Parkı girişi, sedir ormanı, kalker, 1200-1300 m, 17.xi.1993, *B. Mutlu* 163 HUB 36701! Eğridir, Yaka Köy, 2 km güneyi, derin kalker vadisi, *P. nigra-J. excels*a ormanı, 1800 m, 20.v.1973, *Peşmen* 3401, *Erik, Pamukçuoğlu* HUB 36709! Eğridir, Anamas Köyü, Kapız Deresi, kalkerli sarp ve derin vadi, 1250-

1450 m, 05.viii.1974, *H. Peşmen & A. Güner* 1836 HUB 36706! Eğridir, Aksu, Karacahisar Köyü, Başak mevkii, kalkerli vadi, 1000 m, 03.vii.1974, H. Peşmen & A. Güner 1653 HUB 36702!
Konya: Ereğli, Aydos Dağı, Delimahmutlu, Kapız, kayalık, 1600 m, 21.vi.1977, *S. Erik* 2179 HUB 36718! Beyşehir, Kurucuova Köy, Kuzgun tepe, *P. ningra* ormanı, kalkerli K:B. yamaç kayalık arazi, 1300-1500 m, 24.iv.1974, *H. Peşmen & A. Güner* 1019 HUB 36710!
Mardin: Cudi Dağ above Hessana (d. Silopi), 900–1150 m, 11.v.1966, *Davis* 42862A! Savur, 900 m, 24.v.1957, *Davis* 28568, *Hedge*! Dargeçit, Çelik Köyü, Umutlu mezrası, kaya üzeri, 520 m, *S. Arslan* 3297 (GAZI)!
Muğla: Kara Dağ, 750 m, 18.v.1988, *P. Ainsworth* T27/88! Ortaca, Dalyan-Sülüngür Gölü arası, 10 m, kalkerli arazi, makilik dik yamaçlar, 12.ii.1991, *A. Güner* 7999 et al. (HUB)! Fethiye, Babadağı, batı etekleri, gıdırak mevkii, 100 m, 10.v.1984, *E. Tuzlacı* ISTE 53054!
Niğde: Side valley W. of Maden, 30.vii.1969, *J. Darrah* 349!
Samsun: Vezirköprü at Kızılırmak, 400 m, 06.iv.1969, *Tobey* 2446!
Şanlıurfa: Yenice Köyü üstü, Nemrut Dağları, kalker kayalığı tabakalar, taşlık, bozkır, 475-675 m, 26.vi.1988, *Ş. Yıldırımlı* 10791a HUB 36700!
Şırnak: Beytüşebap, Dağdibi Köyünden anayola, kalker kayalığı, 25.v.2004, *A. Dönmez* 11916 (HUB)!
Siirt: Botan Çay, by the bridge 19 km from Siirt, 400 m, 17.v.1966, *Davis* 43220!
Tunceli: Ovacık, Munzur Dağları, Karagöl vadisi, 1300-1500 m, 06.v.1979, *Ş. Yıldırımlı* 1388 *& Ş. Kaplan* HUB 36711!
Yozgat: Sorgun to Çekerek, 1200 m, 27.v.1965, *M.J.E. Coode & B.M.G. Jones* 1598!
General Distribution: Distributed in Europe, Asia, and Africa.

A. tinaei (Tod.) Christenh. Willdenowia 42(2): 284 (2012).
Synonyms: *Cheilanthes tinaei* Tod. in Giom. Sci. Nat. Econ. Palermo 1: 217 (1866); *C. duriensis* Mendonça & Vasc., Anais Inst. Vinho Porto 15(4): 47 (1956); *C. pteridioides* subsp. *tinaei* (Tod.) O. Bolòs & al., Fl. Man. Països Catalans 1213 (1990).
Holotype: [Sicily] "*Messina, Cheilanthes odora* var. *stipites glabrato*" Id. 9541 (PAL).
Isotype: Id. 9542 (PAL) (see Nardi, Rasbach & Reichstein, 1979).
Plant up to 25 cm, rhizome covered with brown long scales. Fronds bipinnate 5–25 × 1–2.5 cm, shortly and sparingly pilose when young, later ± glabrate above, scattered 2-5-celled red glandular hairs beneath; stipe densely covered with long scales at base and with a few scattered scales further up when young then almost glabrous, brown-black, 1–10 cm. Pinnae 0.5–1.5 × 0.3–0.5 cm with very short stalks c. 1 mm. Pinnule 0.5–2 mm broad. Pseudoindusium with rounded, entire membranous margin.
Habitat: Coastal, bare rocks, sea level to 1250 m.
Distribution in Turkey:
Istanbul: Büyükada, Eskibağ, kayalıklar, 17.08.1977, H. Demiriz, B. Tütel, A. Aydın (ISTE 31028!)
General Distribution: N.W. Africa, Portugal, S. Europe.

Cryptogramma R.Br., Narr. Journey Polar Sea [Franklin] 767 (1823).
Rhizome creeping to ascending covered with light brown to black long scales. Fronds dimorphic, tripinnate; sori terminal on veins protected by recurved membranous lateral margins of segments.

C. bithynica S.Jess., L.Lehm. & Bujnoch, Fern Gaz. 19(2): 52 (2012).

Holotype: Northwestern Turkey: Uludağ southeastern of Bursa: silicate scree near the roadway, NNE of the summit of Uludağtepe, 1770 m, 09.ix.2009, leg. *S. Jesen & L. Lehmann* (SJ-3820), JE. Isotype: 09.ix.2009, leg. *S. Jesen & L. Lehmann* (SJ-3820), ANK!

Plant 10(–22) cm, - covered witb light brown long scales. Fronds tripinnate, green, reddish at the end of the fronds, glabrous above, veins visible at and of the lobes in white-yellow colour. Stipe straw-coloured to greenisb, glabrous to sparsely covered with ligbt brown scales. Fertile fronds 8–10 × 3–4 cm; stipe 6–7 cm. Pinnae 2 × 1–2 cm; pinna stalks 1–3 mm. Pinnules linear-lobed, convolute at the edge of lobes. Vegetative fronds slightly thick and relatively tough, 8–10(–22) × 3–4.5 cm, broadly deltate; stipe 5–6 cm. Pinnae ovate to orbicular, 1.5–2.5 × 1–2.5 cm; pinna stalks 1–3 mm. Pinnules lanceolate-lobed. Sori terminal on veins protected by recurved margins of lobes.

Habitat: Silicate scree near the cycle roadway, 1700–2300 m.

Distribution in Turkey:

Northwestern Turkey: Uludağ soutbeastern of Bursa: silicate scree near the roadway, NNE of the summit of Uludağtepe, 1770 m, 09.ix.2009, leg. *S. Jesen & L. Lehmann* (SJ-3820), JE. Isotype: 09.ix.2009, leg. *S. Jesen & L. Lehmann* (SJ-3820)(ANK)!

General Distribution: Endemic to Turkey.

C. crispa (L.) R.Br. ex Hook., Gen. Fil. pl. 115B (1842).

Synonyms: *Osmunda crispa* L., Sp. Pl. 1067 (1753); *Allosorus crispus* (L.) Bernh. in Schrad Jour. 1(2): 36 (1800).

Type: Habitat in Anglia, Helvetia, Herb. Sloane 85: 128 (BM-SL).

Plant to 30 cm, rhizome covered with brown-black long scales. Fronds thin, tripinnate, green, reddish at the end of the fronds, glabrous above, veins visible at and of the lobes in white-yellow colour. Stipe straw-coloured to greenish, glabrous. Fertile fronds 15–30 × 2.5–5 cm; pinna stalks 8–20 cm. Pinnae 2–5 × 1–1.5 cm; stipe 1–6 mm. Pinnules linear-lobed, convolute at the edge of lobes. Vegetative fronds ovate to deltoid–ovate, 15–20 × 3–4 cm; pinna stalks 4–11 cm. Pinnae narrowly ovate, 1.5–3 × 0.7–1.8 cm; pinna stalks 1–4 mm. Pinnules lanceolate-lobed. Sori terminal on veins protected by recurved margins of lobes.

Habitat: Screes, 200–2400 m.

Distribution in Turkey:

Artvin: Arhavi, above Dikyamaç village, 2200 m, 26.vii.1974, *M. Çoşkun* AEF 19! Çoruh, Şaval Tepe above Murgul (igneus), 2000 m, 13.viii.1957 *Davis* 32393 & *Hedge*! Şavşat, Kocabey Kışlası, Camız patlatan mevkii, kayalık alanlar, 1900-1950 m, 14.v.2004, *H. Altınözlü* 3945 (HUB)! Kaçkal Dağı, Pırnallı Üst Yaylası, Cehennem Deresi Mevkii, 1750-3100 m, 12.vii.1984, *Demirkuş* 2641b HUB 36758! Arhavi, Dikyamaç Köyü yaylası, Arpaçay civarı, 2200 m, *M. Coşkun* AEF!

Rize: Kaçkar Mountains, east of Elevit, north of road beyond village, 2365 m, 27.ix.2008! Çamlıhemşin, Amlakıt Yaylası, çayırlık, 1350 m, 10.viii.1984, *A. Güner* 6117 & *M. Vural* HUB 36755! Çamlıhemşin, Amlakıt Yaylası, Kayguttan Çovinovit yoluyla yayla, kalkerli arazi, alpinik step, 2200-2720 m, 19.vii.1974, *A. Güner* 1087 HUB 36753! Çamlıbemşin, Yukarı Amlakıt Yaylası-Kışyatağı arası, *Rhododendron caucasicum* çalılığı, granit anakaya, 2200-2350 m, 20.ix.1979, *A. Güner* 2190 HUB 36754!

General Distribution: Europe and Caucasus.

Cosentinia Tod. Giorn. Sci. Nat. Econ. Palermo 1: 219 (1866).

Rhizomes sbort-creeping to erect with long linear brown scales. Fronds pinnate, both

surfaces of the frond covered, densely below, with long whitish multicellular hairs.

C. vellea (Aiton) Tod. Giorn. Sci. Nat. Econ. Palermo 1: 220 (1866).

Synonyms: *Acrostichum velleum* Aiton Hort. Kew. 3: 457 (1789). *Notholaena vellea* (Aiton) Desv. in J. Bot. Appl., 1:92 (1813) non R. Br. (1810); *N. lanuginosa* (Desf.) Desv. ex Poir., Fragenta Phytographiae Australiae 5 (1865); *Cheilanthes vellea* (Aiton) F. Muell. Domin Bibl. Bot. 85. 133 nota. (1913); *Acrostichum catanense* Cosent., Atti Accad. Gioenia Sci. Nat. Catania 1/2: 207 (1827); *Cheilanthes catanensis* (Cosent.) H.P.Fuchs, Brit. Fern Gaz. 9(2): 45 (1961).

Lectotype: Portugal, 1777, *F. Masson s.n.* BM000829683 (BM)!

Plant 10–20 cm, rhizomes brown with long linear pale brown scales. Fronds pinnate, 8–16 × 1.5–4 cm, green above and brownish below, both surfaces of the frond covered, densely below, with tangled long whitish multicellular hairs; stipe brown, 1–4.5 cm, densely covered with hairs when young, becoming glabrous when mature, young fronds almost sessile, lobed, 0.5–2 × 0.3–0.8 cm. Sori not discrete, sporangia spread along veins from leaf margin, ± protected by recurved but not modified leaf-margin.

Habitat: Dry limestone, calcareous rocks, sea level to 300 m.

Distribution in Turkey:

Ankara: Beynam, Karaçam ormanı, 1300-1500 m, 15.v.1986, Ş. Yıldırımlı 9221 HUB 36713!

Antalya: Kumluca, Adrasan Köyü kuzeyi, serpantin arazi, 300 m, 29.ii.1980, *H. Peşmen* 4791 *& A Güner* HUB 36721!

Aydın: Priene, 100 m, 09.iv.1965, *Davis* 40788! Milet harabeleri, *R. Lampinen* 7441 ISTE 63662!

Bolu: Eğerci'den Yedigöller'e 4. km, Yağmurca Köyü ilerisi, 193 m, 03.xi.2001, *A. Dönmez* 10387 *& S. Işık* (HUB)! Kıbrıscık, Kıbrıscık'tan Beypazarı'na 5 km, *Paliurus spina-christi* açıklığı, 1110 m, 08.viii.2010, *A. Dönmez* 17616 *& Z. Uğurlu* (HUB)!

Çankırı: Eldivan, Seydiköy üstü, step, 1300-1350 m, 09.viii.1984, *Ş. Yıldırımlı* 7409 HUB 36716!

Hatay: İskenderun, Musa Dağı, Kale ilerisi, P. brutia ormanı, 200 m, 30.iii.1995, A. Dönmez 4423 (HUB)!

Isparta: Ş.Karaağaç, Kızıldağ Milli Parkı girişi, Sedir ormanı açıklığı, kalker, 1200-1300 m, 18.xi.1993, *B. Mutlu* 180!

İçel: Anamur'un üstü, Kayalıklarda 200 m, 06.iii.1977, *M. Koyuncu* HUB 36722!

Kastamonu: Hanönü, Karapınar Köyü'nden, Derencik Köyü'ne gidiş, köprü çevresi, çakıllı yamaçlar, 26.ii.2010, *A. Dönmez* 16603 *& Z. Uğurlu* (HUB)!

Kayseri: Yılanlı Dağ, 1200 m, 12.vi.1975, *M. Coşkun & N. Çelik* HUB 36719!

Muğla: Marmaris-Emecik, 5 m, 25.iii.1956, *Davis* 25349 *& O. Polunin*! Marmaris, Hisarönü to Turgut, 20 m, 15.iv.1965, *Davis* 41147! Ören, 50–100 m, 10.iv.1965, *Davis* 40855! Köyceğiz, Yargı Köyü, Yargı Deresi, 60-80 m, sarp ve derin vadi, kalkerli kayalık yamaçlar, kazmofit, 24.v.1981, A. *Güner* 9322, *M. Vural & H. Şağban* HUB 36720! Köyceğiz, Sultaniye, Kersele Deresi, dere yatağı, metamorfik arazi, 15-30 m, 21.v.1991, *A. Güner* 9195, *M. Vural & H. Şağban* HUB 36715!

General distribution: Macaronesia, Mediterranean region including S. Europe and North Africa and east to Turkey, Egypt, Yemen and Oman.

Note: *Cosentinia vellea* has two subspecies, a tetraploid *C. vellea* subsp. *vellea* and a diploid *C. vellea* subsp. *bivalens* (Reichstein) Rivas Mart. & Salvo. On macromorphological characters the two are indistinguishable, but can be separated by comparison of spore size and stomatal length (see Haou et al., 2011). Of four Turkish

specimens for which spores have been measured, three correspond with subsp. *vellea* [64-(67)-71 µm: *Davis 25349,40855, 41147*] and one with subsp. *bivalens* [55-(57)-62 µm: *Davis 40788*], although cytological verification is still lacking.

Paragymnopteris K.H. Shing, Indian Fern J. 10(1–2): 227 (1994) [1993].
Rhizome short-creeping, covered with long, linear scales. Fronds pinnate, linear-lanceolate scales along the midrib above and covered with lanceolate brown scales below.
P. marantae (L.) K.H. Shing, Indian Fern J. 10(1–2): 229 (1994) [1993].
Synonyms: *Acrostichum marantae* L., Sp. Pl. 2: 1071 (1753). *Ceterach marantae* (L.) DC., Fl. Franc. ed. 3. 2: 567 (1805); *Cheilanthes marantae* (L.) R.Br., Prodr. Fl. Nov. Holland. 145 (1810); *Notholaena marantae* (L.) R.Br., Prod. Fl. N. Holl. 146 (1810); *Cincinalis maranthae* (L.) Desv., Berl. Mag. 5. 312 (1811); *Gymnogramma marantae* (L.) Mett., Fil. Hort. Bot. Lips. 43 (1856); *Gymnopteris marantae* (L.) Ching, Acta Phytotax. Sin. 10: 303 (1965); *Paraceterach marantae* (L.) R.M.Tryon, Amer. Fern J. 76(4): 186 (1986).
Lectotype: *Pierre Magnol s.n.* Herb. Linn. 1245.12 (LINN)!
Plant 10–30 cm. Rhizome covered with long, linear light brown scales. Fronds pinnate-pinnatisect, 10–30 × 1.2–4.5 cm, linear-lanceolate scales only along the midrib above, lower frond surface densely covered with lanceolate brown scales; stipe 4–20 cm, with scattered brown scales. Pinnae 1–2.5 × 0.5–1.2 cm, 3–7 lanceolate or broad triangular lobed, main lobe almost lyre-shaped, edge of pinnae undulate or simple; pinna stalks 1–2 mm or sessile. Sori not discrete, sporangia spread along veins from leaf margin, ± protected by slightly recurved and modified leaf-margin.
Habitat: Serpentine rocky slopes, sea level to 1400 m.
Distribution in Turkey:
Adana: Karsantı, Kumbükü, Hızar yolu, ca. 880 m, 05.v.1972, *E Yurdakul* ANK 1768!
Feke: Sencan Dere between Belankey and Suphandere, metamorphic rocks, 100 m, 02.vii.1952, *Davis 19586B, Dodds, Cetik*! Bahçe (N. Amanus), Dumanli Dağ above Haruniye, shady metamorphic rocks, 1200 m, 19.iv.1957, *Davis 26845, Hedge*!
Ardahan: In Felsritzen etwa 10-15 km östlich von Kosor zw. Göle und Olta, 22.iv.1957, *E. Sauer 306/57*!
Artvin: Yusufeli, Altıparmak Köyü üzeri, *P. sylvestris-P. orientalis* ormanı, 1250 m, 20.v.1983, *A. Güner* 4829 & *M. Vural* (GAZI)!
Erzincan: Erzincan'ın 30 km batısında serpantin boğazı, ca. 1500 m, 18.vii.1958, *H. Birand* ANK 10909! Keşiş dağ above Cimin, among igneous rocks, 2700 m, 28.vii.1957, *Davis 31652, Hedge*!
Giresun: Şebinkarahisar, Arslanyurdu Deresi, ca. 1380-1460 m, 28.viii.1976, *K.P. Buttler* ANK 21819!
Hatay: Hassa to Dörtyol, mountain road, slopes above Dörtyol, 1100 m, *A.J. Byfield & D. Pearman* B 2620 ISTE 73362!
İçel: Mersin, Fındıkpınar, Demirışık, *P. brutia* altı, nemli yerler, 24.vi.1971, *T. Uslu* ANK 526!
Kahramanmaraş: Andırın, Elma Dağı, orman açıklığı, 1550 m, 22.vi.1979, *E. Tuzlacı & M. Saraçoğlu* ISTE 42386!
Kastamonu: Tosya, Sekiler Köyü, Seki Deresi, kayaların arası, ca. 1100 m, 28.ix.1977, *M. Kılınç* ANK 6866!
Konya: 2 km from Çamlık village, Akseki-Beyşehir area, 1360–1370 m, 03.vi.2003, *R.D. Reeves* 2693 & *N. Adıgüzel*!

Muğla: Marmaris, 50 m, 13.iv.1965, *Davis* 41021! Marmaris, Pinetum brutiae, on serpentine, shady rocks, 30 m, 24.iii.1956. *Davis 25,255, O.Polunin*! Nordwestlich Köyceğiz oberhalb Ağla, Felsspalte im Kiefernforst, 950 m, 30.vi.1973, *F. Holtz* 428, *P. Hanel, T. Kesercioğlu*! Köyceğiz, Sultaniye, Kersele Deresi, dere yatağı, metamorfik arazi, 5-30 m, 21.v.1991, *A. Güner* 9195, *M. Vural, H. Şağban* HUB 36715! Sandras Dağı, Çiçekbaba Tepesinin güney yamaçları, 1700 m, 14.vii.1978, *N. Özhatay & E. Özhatay* ISTE40635!

Samsun: Ladik Istasyon, Karadağ, 1050 m, 08.v.1965, *Tobey* 947! Vezirköprü at Kızılırmak, 400 m, 20.iv.1969, *Tobey* 2451!

Zonguldak: Dirgine to Devrek, cliff edges (serpentine), 180m, 18.vii.1962. *Davis 37906, Coode, Yaltirik,*!

General Distribution: Mediterranean area, northern Austria and Caucasus. C. & S. Europe, Macaronesia, N. Africa.

Pteris L., Sp. Pl. 2: 1073 (1753).

Fronds pinnate to bipinnate, green and glabrous, midrib and secondary veins distinct.

P. cretica L., Mant. Pl. 130 (1767).

Synonyms: none.

Lectotype: *Pietro Arduino s.n.* Herb. Linn. 1246.7 (LINN)!

Plant 30–70 cm. Rhizomes short-creeping dark brown with dark brown scales. Fronds pinnate to bipinnate, green and glabrous, midrib and secondary veins distinct. Pinnae ≤ 7 pairs, often with a long basal segment. Fertile fronds serrate only at the end, convolute at the edge of lobes, 40–70 × 15–20 cm; stipe 20–40 cm, pinnae 10–15 cm and sessile or with c. 1 mm stalk. Vegetative fronds serrate at margin, 30–70 × 10–20 cm; stipe glabrous, 20–35 cm. Pinnae 5–20 cm, sessile or with 1–3 mm stalk. Sori submarginal, in a continuous line protected by scarious recurved leaf-margin.

Habitat: Shady banks and shady damp places in deciduous forests, sea level to 800 m.

Distribution in Turkey:

Artvin: 10 km south of Hopa on road to Artvin, 120 m, 25, 25.ix.2005, *B. Güner* et al., TUDI 46! Arhavi, Dikyamaç village, 800 m, 15.vii.1994, *M. Coşkun* AEF 20! Çoruh, 1 km südwestlich von Hopa neben Küstenstrabe steiler, 05.viii.1973, *F. Holtz* (01.056), *P. Hanel & T. Kesercioğlu*! Çoruh, Borçka, Hopa, 300 m, 21.vi.1957, *Davis & Hedge* 29832! Çoruh, deciduous forest, 2 ft. 6 ins. high, 18.viii.1966, *Tong* 496! Çoruh, Hopa, near sea level, 22.vi.1957, *Davis & Hedge* 29876! Hopa, Sarp Köyü, 5 m, 11.iv.1982, Ş. Yıldırımlı 4414 HUB 36746! Hopa, Kemalpaşa-Sarp arası denize dik kayalıklar, 0-50 m, 19.v.1985, *Ş. Yıldırımlı* 7895 HUB 36751! Hopa, orman altı, 0-50 m, 25.01.1992, *D. Osmanoğlu & Z. Aytaç* 4473 (GAZI)! Murgul, Meratit Köyü, 02.viii.1959, *R. Çetik & Davis* ANK 20500!

Giresun: Denize yakın çalılık ve ıslak yerlerde, 07.vii.1958, *H. Birand*, A 10692a! Gengene Köyü, Fagus ormanı, 24.vi.1977, *Y. Akman* ANK 6977!

Ordu: Fatsa, rocks above Kayalar Dere, 60 m, 23.iv.1963, *C. Tobey* 46!

Rize: 2 km south east of Rize, 100 m, 04.viii.1974, *J.R. Akeroyd* 173! Shady banks, 100–200 m, 21.viii.1952, *Davis* 20785 & *Dodds*! Çamlıhemşin, Aşağı Vice Mahallesi üstü, karışık orman ve nemli çayırlık, 500-600 m, 13.vii.1979, *A. Güner* 2095 HUB 36750! Çamlıhemşin, Boğazıçik Köyü, Pogina çevresi, karışık orman, 650 m, 04.ix.1978, *A. Güner* 1820 HUB 36748! Alipaşa Köyü civarı, 29.vii.1956, *K. Karaosmanoğlu* HUB 36749!

Trabzon: Valley above Çaykara, 700 m, 05.viii.1957, *Davis & Hedge* 32107! Sürmene,

Gökçesu Mahallesi, İdrum tepe çevresi, 350-550 m, 04.vii.1997, *H. Duman* 6464 (GAZI)!

General Distribution: S. Europe, W. Syria, Caucasus, subtropical Asia, E. and S. Africa, N. America, Hawaii.

P. vittata L., Sp. Pl. 1074 (1753).

Synonyms: *P. ensifolia* Poir. in Lam, Encycl. 5: 711 (1804); *P. diversifolia* Sw. Syn. Fil. 96: 288 (1806); *P. costata* Bory, Sp. Pl. 5: 367 (1810); *P. inaequilateralis* Poir. Encycl. 4: 601 (1816); *Pycnodoria vittata* (L.) Small, Ferns Florida 89 (1931).

Lectotype: Herb. Linn. 1246.3 (LINN)!

Plant 10–70 cm. Rhizomes short-creeping, brown with fine long scales. Fronds pinnate, 10–70 × 5–20 cm, green, long thin scales along with midrib; stipe 1.5–10 cm, yellowish brown with thin long scales. Pinnae (2–)6–10 × 0.3–1 cm, ≥10 pairs, longer at apex of frond, reducing in length towards frond base, narrowly lanceolate, undivided, serrate, almost sessile. Sori submarginal, in a continuous line protected by scarious recurved leaf-margin.

Habitat: Shady rocks or serpentine.

Distribution in Turkey:

Antalya: Kemer-Ulupınar arası, 200 m, 08.vii.1979, *H. Peşmen* 4380 & *A. Güner* HUB 36744! Kemer, Götnük Deresi, Kalker vadisi, 50-200 m, 22.iii.1979, *H. Peşmen* 4199 & *A. Güner* HUB 36743! Alanya, *P. brutia* altı, c. 300 m, 04.viii.1982, *Ş. Yıldırımlı* 4452 HUB 36741! Düden Şelalesi, 23.iv.1976, *N. Kızılgül* AEF 5714!

Hatay: Valley above Dörtyol, S. bank, N. facing, 150 m, 12.viii.1969, *J. Darrah* 534, 634, 620! Antakya, Harbiye, şelale civarı, 180 m, *M. Coşkun* 321, *B. Şener & F. Ilisulu*! Mersin: Silifke-Anamur arasında Değirmenönü, köy değirmeni yakını, 50 m, 09.ix.1962, *H. Kayacık* 2958!

General Distribution: Europe and Asia.

CONCLUSION

In the first volume of the *Flora of Turkey* (Henderson, 1965) the family currently recognised as Pteridaceae was represented by nine species from five genera and classified in five different families. Since this publication, further new records of *Cheilanthes tinaei* (Davis, 1988) and *Cryptogramma bithynica* (Jessen et al., 2012), have been published. In this revision the single family Pteridaceae in Turkey includes 11 species from seven different genera. Families Adiantaceae, Cryptogrammaceae, Gymnogrammaceae and Sinopteridaceae have been combined in the family Pteridaceae (see Christenhusz et al., 2011). The names of the genera *Anogramma*, *Adiantum*, *Cryptogramma* and *Pteris* have not changed since 1965. However, Turkish *Cheilanthes* species are now placed in three different genera: *Allosorus*, *Cosentinia* and *Paragymnopteris*. *Cheilanthes marantae* is a synonym of *Paragymnopteris marantae* and *Cheilanthes catanensis* is a synonym of *Cosentinia vellea*, whilst *Cheilanthes persica*, *Cheilanthes acrostica* and *Cheilanthes tinaei* are now placed within *Allosorus* (Christenhusz et al., 2011; Greuter & Raab-Straube, 2012).

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COMPILED BY M. GIBBY & A.M.PAUL

SHORT NOTE

RETYPIFICATIONS OF *ADIANTUM INCISUM* (PTERIDACEAE) AND *PTERIS INTERRUPTA* (THELYPTERIDACEAE)

Species-rich eastern India includes the states of Sikkim, West Bengal, Arunachal Pradesh, Meghalaya, Assam, Tripura, Manipur, Nagaland and Mizoram (Ghosh et al. 2004). Rejection of records of a number of new species and new distributional records from this region by Fraser-Jenkins (2008, 2012) necessitate a revision to the treatment by Ghosh et al. As a part of ongoing revision of the ferns of Eastern India, *Adiantum incisum* Forssk. (Pteridaceae) and *Pteris interrupta* Willd. (current name: *Cyclosorus interruptus* (Willd.) H.Ito, Thelypteridaceae) are retypified.

***Adiantum incisum* Forssk., Fl. Aegypt.-Arab. 187. 1775.**
Lectotype (designated here): Yemen. Al Hadiyah ['Hadîe'], 1763, *P. Forsskål s.n.* (C10001579, Isolectotype C10001580 images!).

The name *Adiantum incisum* was proposed by Linnaeus's disciple Peter Forsskål (1775) based on his collection from Yemen. The Botanical Garden, University of Copenhagen, Denmark (C) stores two specimens: C10001579 (http://www.daim.snm.ku.dk/digitized-type-collection-details-simple?catno=C10001579) and C10001580 (http://www.daim.snm.ku.dk/digitized-type-collection-details-simple?catno=C10001580). C10001579 is a complete plant with Forsskål's field label "Adianthum *incisum Hadîe", thus undoubtedly original material and type of *Adiantum incisum*. C10001580 is single isolated frond. It does not have Forsskål's annotation but resembles C10001579 and is most probably from same gathering.

During a revision of the ferns of tropical East Africa the renowned botanist the late Dr. Bernard Verdcourt selected the specimen in C with the original field label (i.e. C10001579) as lectotype (see Verdcourt 2002: 55). Although his lectotype selection is taxonomically correct, it unfortunately did not fulfill requirements specified in the Melbourne Code (McNeill et al. 2012). Lectotypification statements published on or after 1 Jan 2001 must include the phrase "designated here" (*hic designatus*) or an equivalent (McNeill et al. 2012 Art. 7.10). Verdcourt's lectotypification was published in 2002 without such statement. Here it is republished to fix the application of the name *A. incisum*.

***Pteris interrupta* Willd., Phytographia 13 t. 10 f. 1. 1794. [Sep 1794].**
Lectotype (designated here): Willdenow (1794), Phytographia t. 10, f. 1. [Icon].
Epitype (designated here): India. Tamil Nadu ["Madras"], Aug 1794, *Rottler ex Klein s.n.* (BW19770011, Isoepitype BW19770012).

Pteris interrupta (*Cyclosorus interruptus*) is the type of the name *Cyclosorus* Link. Fosberg & Sachet (1972) considered a specimen (BW19770011; http://herbarium.bgbm.org/object/BW19770011) in Herb. Willdenow from Herbarium Berolinense, Berlin (B) as the type of *Pteris interrupta* and this has been considered to be a lectotype. Holttum (1973) also treated it as such.

The name *Pteris interrupta* was published in September 1794 by Willdenow, but the

supposed type sheet (BW19770011) was annotated by Willdenow as "Klein Ind. 1797. W." This indicates that Willdenow received this specimen in 1797 from Johann Gottfried Klein, a missionary and botanist from South India. Thus this specimen is not original material, rather a later collection.

The putative type (BW19770011) also carries the annotation "Pteris sp. n.? Aug. 1794. Auf den Reise nach Madras" written by Johan Peter Rottler, a missionary and botanist from South India (Dr. Frits Adema *pers. comm.* 2015). However the annotation "(Klein)" was written by Willdenow. So this specimen was actually collected by Rottler in August 1794 during a trip through Madras (now Tamil Nadu, India) and reached Willdenow through Klein. It is unlikely that Rottler's collection (in August 1794) was subsequently studied and published by Willdenow within short period of one month (in September 1794).

This sheet does not carry Willdenow's name *Pteris interrupta*, but Willdenow's annotation "Asp. obtusatum 1a." The name *Aspidium obtusatum* Sw. was published in 1801 by Swartz. As explained by Fosberg & Sachet (1972: 8) Willdenow sent a pinna from BW19770011 to Swartz. The pinna, now in the Natural History Museum, London (BM), was identified by Swartz as *Aspidium obtusatum* and he informed Willdenow of this.

Another sheet (BW19770012; http://herbarium.bgbm.org/object/BW19770012) exists in Herb. Willdenow in B carrying two isolated fronds and Willdenow's annotation "Asp. obtusatum 1b." These two specimens resemble BW19770011 and were most probably collected by Rottler from same individual or population.

Thus no type specimen for *Pteris interrupta* is known to exist. The illustration "t. 10 f. 1." of *Pteris interrupta* in the protologue (Willdenow 1794) is the only original material and I select it as lectotype and BW19770011 as epitype.

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BOOK REVIEW

Ferns and Fern-allies of Nepal, Volume 1. Fraser-Jenkins C.R., Kandel D.R. & Pariyar S. 2015. pp 508. ISBN: 978-9937-2-9496-6 : National Herbarium and Plant Laboratories, Department of Plant Resources, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Christopher Fraser-Jenkins has been studying Himalayan pteridophytes for over 30 years and for much of this time also living in Nepal. He is the pre-eminent expert of ferns in Himalayan region and also possesses vast expertise on the ferns of wider Asia and Europe. In this volume (the first of 2) the results of his studies of Nepalese ferns and lycophytes are summarised. The richness of the flora is highlighted by the fact that 580 species and subspecies will be included once the second volume has been completed. By comparison, England and Wales occupying an area of similar size if not topography, has about 80 taxa including naturalised introductions.

The introduction to this volume includes interesting and useful summaries on phytogeography, collectors, collections and publications pertaining to Nepal. Then follows a section outlining the classification utilised (basically that of Smith et al. (2006)), and a longer section on the apparent deficiencies of recent molecular-based phylogenies. Fraser-Jenkins is well known for his scepticism of the utilisation of small sections of DNA as a basis for classification. His frequent strongly stated views and objections of studies that don't coincide with his ideas based on traditional morphological taxonomies are presented again here. Next are short sections with notes on the history and progress of the current volume and the format of the species accounts. This is followed with a list of accepted species and subspecies included in both Volume 1 and 2. The list of taxa to be published in Volume 2 includes taxonomic and nomenclatural notes on various species as well as new combinations, new species and even a new genus, *Katoella* (Davalliaceae). This latter example highlights one of the inconsistencies of his morphological approach. Davalliaceae is split into a number of small genera whereas the much larger and morphologically diverse family Thelypteridaceae contains a single genus, *Thelypteris*. Recent molecular studies are starting to unravel the phylogeny of this family, but will they be acceptable to Fraser-Jenkins? Maybe we will find out when volume 2 is published. Intriguingly, in this list, *Dryopsis* is lumped back in to *Ctenitis* without explanation, which seems to be at odds with both morphological and molecular evidence. Hopefully this decision will also be explained in more detail in the second volume.

The main bulk of the book is taken up with the taxonomic accounts of 20 families including those of the Lycophyta and the early branching fern orders through to the Pteridaceae in the Polypodiales (Vittariaceae remains separated and is the concluding family to Volume 1). The amount of information and knowledge collated here is astounding. For example, a page opened at random revealed the treatment of *Aleuritopteris bicolor*. It starts with a list of synonyms and misapplied names. Then follows a short overview of its confused history, cytology, ethnobotany and a brief comparative description. Next is a list of dozens of examined specimens listed under the different Nepalese regions and finally a note on its total distribution and status in Nepal. It should be emphasised that this is not an identification manual as such and no keys are provided. To confidently identify one of the many different *Pteris, Onychium* or *Aleuritopteris* species without prior experience would be difficult. However for smaller genera, such as the difficult *Coniogramme*, accurate identification should be possible

from the brief descriptions. Incidentally under *Coniogramme* and several other genera, Fraser-Jenkins, with some justification, draws attention to the many errors of taxonomy and nomenclature contained within the recent Flora of China Pteridophyta treatment. As we have come to expect, his opinion is strongly presented, finishing with a radical proposal to resolve the problems. In regard to *Coniogramme* I have spent some time trying to sort out the species in cultivation and in my view his ideas make far more sense than those found in the Flora of China account.

As is often the case in Fraser-Jenkins' works, many interesting comments and observations are concealed under various species accounts, including unexpected notes on species far away from Nepal. For example, both *Adiantum viridimontanum* and *Pteris longifolia* of the New World are reduced to subspecies of *Adiantum pedatum* and *Pteris vittata* respectively. Several important accounts clarifying the taxonomy and distribution of difficult genera are included. *Onychium* is comprehensively revised for the region, with descriptions of two new species and a new hybrid. *Selaginella* and *Pteris* are the two largest genera in Volume 1 with 23 and 27 species respectively. I noticed that the name *Pteris longipes* is considered to have been misapplied and is actually an earlier name for the well-known *P. wallichiana*. Fraser-Jenkins favours rejection of the former name and I suspect a formal proposal is in the pipeline. Other complex genera such as *Huperzia, Adiantum, Aleuritopteris* and *Microlepia* are very fully treated and the latter, in particular, includes much new and useful information. One important name change affects the widespread and common fern, *Dennstaedtia scabra*. The rules of priority will mean *D. zeylanica* now takes precedence.

At the end of the book are 138 colour plates that show many of useful discriminating characters for a range of species. Finally there is an appendix explaining in detail the confused identity and nomenclature of *Athyrium setiferum* and the index.

I noted very few printing or spelling mistakes. Only one error stood out, *Sambucus edulis* (page 270), presumably meaning *S. nigra* (Elder). This is an example that demonstrates the author's intimate knowledge of Asian ferns; he notes that living fronds of *Coniogramme procera* smell strongly of Elder when crushed. I doubt that this small but useful piece of information has ever been published previously.

Rather frustratingly there is no bibliography in the present volume and presumably this will be included in Volume 2. Also a separate and complete list of new taxa and combinations would be most useful. Although they are included in bold type in the index of this volume I noticed at least one had been overlooked. The book is reasonably well produced although the binding leaves much to be desired and my copy is already showing signs of distress.

In summary, Chris Fraser-Jenkins and his co-authors are to be warmly congratulated on producing this landmark in Asian pteridology. It will provide a detailed baseline of data that will be used widely throughout the Himalayan region and beyond. I and many other pteridologists, both professional and amateur, will eagerly await the arrival of the second volume.

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T. PYNER

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STEVENSON, D.W. & LOCONTE, H. 1996. Ordinal and familial relationships of pteridophyte genera. In: CAMUS, J.M., GIBBY, M. & JOHNS, R.J. (Eds) Pteridology in perspective, pp. 435-467. Royal Botanic Gardens, Kew.

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